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Summary of the Geology of the Chicago Area.
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and for determining foundation conditions for major structures. Today's rapidly increasing problems of waste management, drainage, and planning effective land use for improvement and growth of the metropolitan area have created a much greater demand for geologic information. This type of special application of geologic data is called "environmental geology" (Frye, 1971). This report presents a general, though brief, summary of the basic geologic data that must be the starting point for those who need geologic information for the solution of specific problems. It is not intended to furnish solutions for the many problems that are constantly encountered in the Chicago area.

The map (pl. 1) shows the distribution of the many different rock types that are exposed or directly underlie the surface soil. The text discusses their origin and explains their classification and general character. Brief descriptions of the deeper rock formations, of the land forms of various types, and of the mineral resources of the area also are included.

Geologic Setting

The geological setting of the Chicago area is shown by two regional maps, one showing the distribution of the bedrock units (fig. 1) and the other the distribution of the glacial deposits that overlie the bedrock (fig. 2).

The bedrock formations are exposed only in the southern half of the area, where glacial and modern rivers have cut through the glacial deposits and where quarries and mines have been opened. The glacial deposits, called drift, mantle more than 95 percent of the area and consist of unconsolidated till, silt, clay, sand, gravel, and peat. They are sharply differentiated and readily distinguished from the much older, consolidated bedrock formations that consist of dolomite, limestone, sandstone, shale, claystone, and coal.

The Chicago area is on a broad, gently sloping arch of the Paleozoic bedrock formations. This arch, called the Kankakee Arch, connects the Wisconsin Arch and the Cincinnati Arch and separates two broad depressions - the Illinois Basin to the southwest and the Michigan Basin to the northeast (fig. 1). The northeastern part of the Chicago area is on the northeastern flank of the arch, as is indicated by the eastward dip of the Silurian formations. The extreme southwestern part of the area is on the southwestern side of the arch, as is shown by the southwestward dip of the Pennsylvanian formations. Stream and glacial erosion truncated the arch and produced a surface that in broad aspects is a plain. As a result, the older rocks are exposed along the axis, or crest, of the truncated arch and the younger rocks are exposed in the bordering basins.

The entire Chicago area was buried under several thousands of feet of glacial ice that spread over the region from the northeast during the Wisconsinan glaciation—the last major advance of the ice. The glaciers were largely part of the Lake Michigan Lobe (fig. 2) but possibly included the margin of the Saginaw Lobe in the extreme southeast and the Green Bay Lobe in the extreme northwest. The Wisconsinan glaciers spread westward nearly to the Mississippi River and southward to central Illinois, and they eroded the Chicago area so intensely that no deposits of earlier glaciers have been found. It is reasonably certain that glaciers of the Illinoian glaciation, which preceded the Wisconsinan, advanced from the Labradorean Center of accumulation in eastern Canada and covered the Chicago area. Deposits of the Illinoian glaciation buried by younger deposits may remain in some of the bedrock valleys. As deposits of the still earlier Kansan glaciers are present southwest of the Chicago area, the northern edge of a Kansan glacier from the northeast also may have covered part of the region. There is no evidence to suggest that glaciers of the earliest glaciation, the Nebraskan, covered the Chicago area.

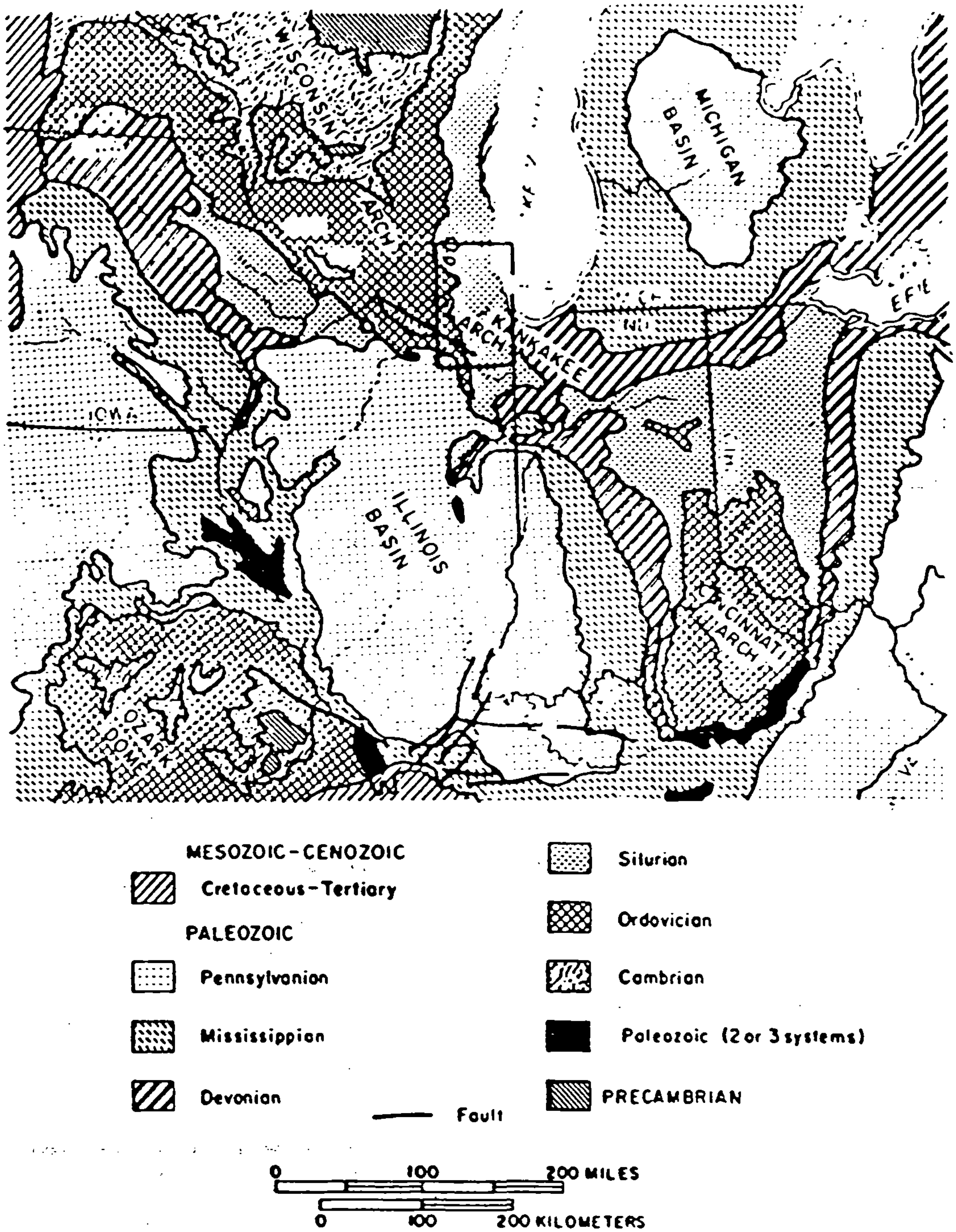

Fig. 1 - Bedrock geology map of the north-central states showing the surface distribution of the geologic systems of rocks, the major structural features, and the location of the Chicago area (after Geological Map of North America, U.S. Geological Survey, 1965).

The glaciers retreated from the Chicago area about 13,500 years ago, by which time Lake Chicago had spread over much of what is now Chicago. Discharge from the lake through the Chicago Outlet to the Illinois Valley continued intermittently until about 3,000 years ago, although a minor discharge may have occurred as

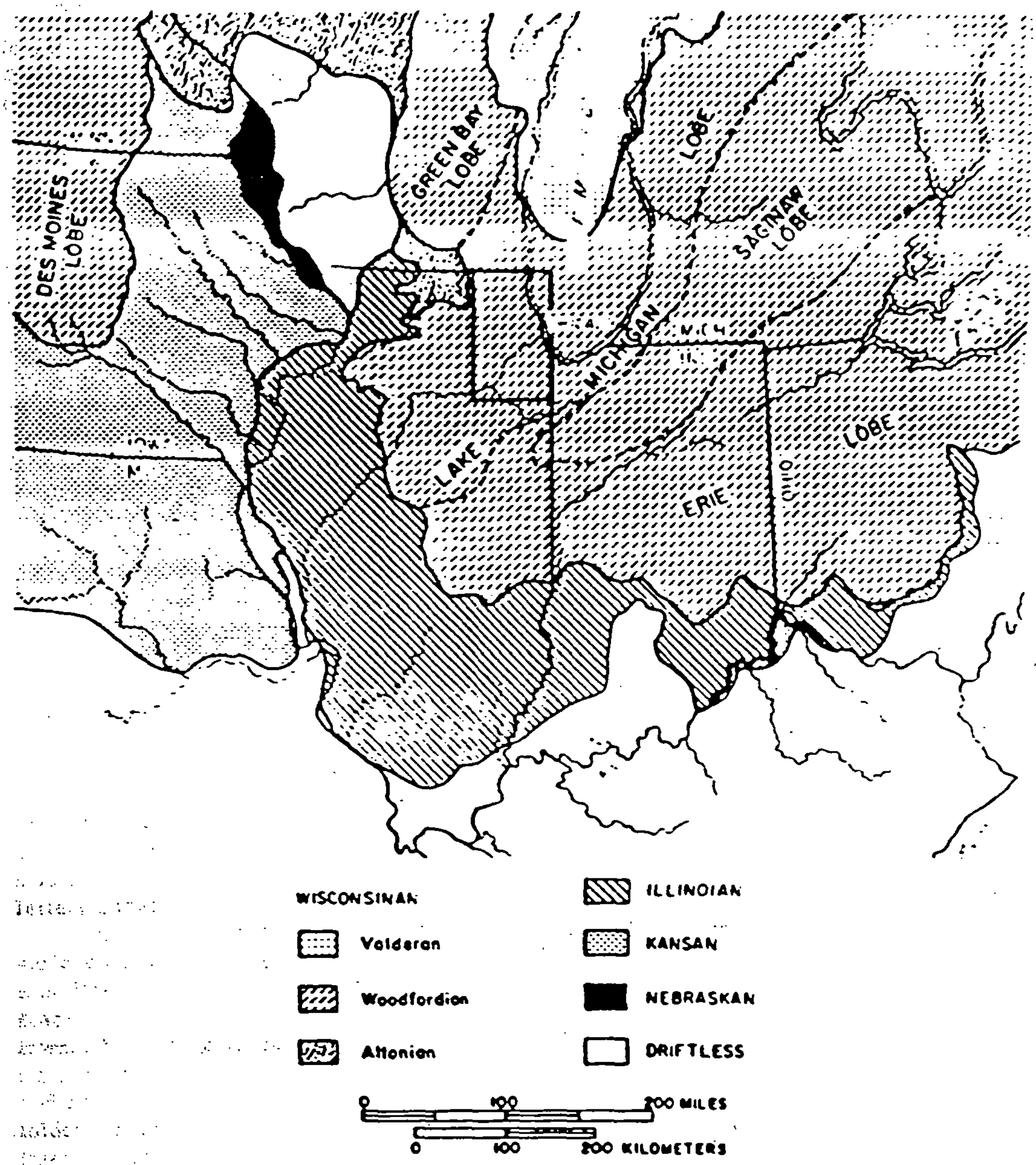

Fig. 2 - Glacial geology map of the north-central states showing the surface distribution of the major drift sheets, the principal Wisconsinan glacial lobes, and the location of the Chicago area (after Flint et al., 1959).

recently as 2,000 years ago. When the glaciers melted, a thin deposit of wind-blown silt (loess) blanketed the area; lakes formed in the depressions, eroded their shores, and made beaches; streams entrenched themselves and began building floodplains; the winds blew sand from the glacial outwash into dunes; vegetation covered the land; and weathering began the process of soil formation.

These processes are still going on. Many of the lake basins have been filled, or partly filled, with silt and peat, and the soil and forests have stabilized the sand dunes and reduced erosion by the streams. To some extent man has reversed the natural processes by tilling the soil, overgrazing the pastures, and cutting the

STRATIGRAPHY

The rock formations in the Chicago area were formed in many ways. Some were deposited in shallow to moderately deep seas that repeatedly invaded the continent. On land, sediments were deposited in rivers, streams, and lakes. Many types of deposits were laid down by melting glaciers and by meltwater flowing from the glaciers. The winds deposited a thin mantle of loess and blew beach sands into dunes.

The common sedimentary rock types in the Chicago area include dolomite, limestone, shale, sandstone, siltstone, and claystone in the bedrock formations, and gravel, sand, silt, and clay in the unconsolidated formations. No igneous and metamorphic rocks are native to the region, except in the deeply buried Precambrian formations, but fragments of these rocks, a few as large as 5 to 10 feet in diameter, were carried into the region by glaciers in such numbers that the common rocks granite, gneiss, schist, basalt, and quartzite — are plentiful along all streams that are actively cutting into the glacial deposits.

STRATIGRAPHIC CLASSIFICATIONS

Stratigraphy is concerned with recognizing changes in the character of the strata, or layers, of rocks, with differentiating the strata into units based on various characteristics, and with determining the age and order of deposition of the units, thus providing classifications by which the rocks can be systematically mapped and described. The development of several classifications, each based on specific characteristics of the rocks and, therefore, independent of each other, provides the different types of units needed for solution of various kinds of geologic problems—units with precise meanings and distinctive names. Several stratigraphic classifications are used in Illinois (Willman, Swann, and Frye, 1958; Frye and Willman, 1970; Willman and Frye, 1970). The classifications used in this report are the rock-stratigraphic, time-stratigraphic, geologic time, morphostratigraphic, soil-stratigraphic, cyclical, and sequence classifications. The principal classifications and the named units used in the Chicago area are shown in figures 5 and 15.

The rock-stratigraphic classification differentiates the rocks according to lithology, or kind of rock. The fundamental unit, called a *formation*, is the unit most useful for mapping, description, and economic purposes. Subdivisions of the formation, called *members*, are based on minor differences in lithology, or are distinctive units too thin or local in distribution to be treated as formations. Adjoining formations that have some common characteristics are combined in units called *groups*, and combinations of related groups are called *megagroups*. Where two rock units grade laterally into each other, or are intertongued, a vertical plane, or cut-off, is arbitrarily used to differentiate the two units in order to avoid repetition of a named unit in a vertical section.

Most formation names consist only of a geographic name and the rank, for instance, Wedron Formation, but formations that are dominantly of one rock type are given a rock name, such as St. Peter Sandstone, and the word formation is omitted. Other units given rock names also include the rank, such as Tiskilwa Till Member. Rock names are capitalized only in the rock-stratigraphic classification.

In time-stratigraphic classification the rocks are classified according to age, or time of deposition, and the units are bounded by time planes that represent a spe-

Fig. 5 - Columnar section of the rock strata in the Chicago area. Abbreviations: Alex.-Alexandrian; Burl.-Burlington; Cin.-Cincinnatian; Desm.-Desmoinesian; Dev.-Devonian; Ed.-Edenian; Fran.-Franconian; Kind.-Kinderhookian; May.- Maysvillian; Miss.-Mississippian; Penn.-Pennsylvanian; Pleis.-Pleistocene; Precam.-Precambrian; Quat.-Quaternary; Rich.-Richmondian; Tremp.-Trempealeauan; Trent.-Trentonian; Up.-Upper; Val.-Valmeyeran.

Time Stratig. System	Series	Stage	Rock Stratigraphy Mega-group	Group	Formation	Graphic Column	Thickness (Feet)	Kinds of Rock
QUAT.	PLEIS				(See fig 15)		0-350	Till, sand, gravel, silt, clay, peat, marl, loess
PENN.	DESM			Kewanee	Carbondale		0-125	Shale, sandstone, thin limestone, coal
					Spoon		50-75	As above, but below No 2 Coal
MISS	VAL				Burl-Keokuk		0-700	Limestone — Only in Des Plaines Disturbance
	KIND				Hannibal			Shale, siltstone — Only in Des Plaines Disturbance
DEV	UP.				Grassy Creek		0-5	Shale in solution cavities in Silurian
SILURIAN	NIAGARAN		Hunton	Kiagani	Racine		0-300	Dolomite, pure in reefs, mostly silty, argillaceous, cherty between reefs
					Waukesha		0-30	Dolomite, even bedded, slightly silty
					Joliet		40-60	Dolomite, shaly and red at base, white, silty, cherty above, pure at top
	ALEX				Kankakee		20-45	Dolomite, thin beds, green shale partings
					Edgewood		0-100	Dolomite, cherty, shaly at base where thick
ORDOVICIAN	CIN	RICH		Maquoketa	Neda		0-15	Oolite and shale, red
					Brainard		0-100	Shale, dolomitic, greenish gray
					Ft Atkinson		5-50	Dolomite, green shale, coarse limestone
		MAY / ED			Scales		90-120	Shale, dolomitic, gray, brown, black
	CHAMPLAINIAN	TRENT	Ottawa	Galena	Wise Lake		170-210	Dolomite, buff, pure
					Dunleith			Dolomite, pure to slightly shaly, locally limestone
					Guttenberg		0-15	Dolomite, red speckled and shale partings
		BLACKRIVERAN		Platteville	Nachusa		0-50	Dolomite and limestone, pure, massive
					Grand Detour		20-40	Dolomite and limestone, medium beds
					Mifflin		20-50	Dolomite and limestone, shaly, thin beds
					Pecatonica		20-50	Dolomite, pure, thick beds
				Ancell	Glenwood		0-80	Sandstone and dolomite, silty, green shale
					St Peter		100-600	Sandstone, medium and fine grained; well rounded grains, chert rubble at base
	CANADIAN		Knox	Prairie du Chien	Shakopee		0-70	Dolomite, sandy, oolitic chert, algal mounds
					New Richmond		0-35	Sandstone, fine to coarse
					Oneota		190-250	Dolomite, pure, coarse grained, oolitic chert
					Gunter		0-15	Sandstone, dolomitic
CAMBRIAN	CROIXAN	TREMP.			Eminence		50-150	Dolomite, sandy
					Potosi		90-220	Dolomite; drusy quartz in vugs
		FRAN.			Franconia		50-200	Sandstone, glauconitic; dolomite, shale
					Ironton		80-130	Sandstone, partly dolomitic, medium grained
		DRESBACHIAN			Galesville		10-100	Sandstone, fine grained
					Eau Claire		370-570	Siltstone, dolomite, sandstone and shale, glauconitic
			Potsdam		Mt. Simon		1200-2900	Sandstone, fine to coarse; quartz pebbles in some beds
PRE-CAM.								Granite

cific moment in time. The time planes chosen for boundaries of time-stratigraphic units are based on a specific reference section, called a type section, and are placed at a position where there is a significant and traceable change in the rocks. Most major time boundaries are at the beginning or end of a sequence of rocks in which a particular fossil, or group of fossils, is found, and fossils are the principal means by which time planes are traced. In strata that generally lack fossils, other criteria are used, such as soils in the Pleistocene System. Except in their type sections, time planes do not necessarily coincide, in fact, commonly do not coincide, with the boundaries of rock-stratigraphic or other units. The fundamental unit of time-stratigraphy is called a *system*. Groups of systems are called *erathems*, and successively smaller subdivisions of systems are called *series*, *stages*, and *substages*.

The time-stratigraphic classification serves as the basis for the geologic time classification, which therefore is not an independent classification. The interval of time during which a system of rocks was deposited is called a *period*. An erathem was deposited during an *era*, a series during an *epoch*, and a stage during an *age*. A substage has no formal geologic time name. The same geographic names are used in both classifications and they are distinguished from the geographic names in all other classifications by having adjectival endings (Silurian System, Silurian Period). In the Devonian System, Upper, Middle, and Lower Devonian Series are formal units and therefore are capitalized. In the other systems, the series have geographic names, and upper, middle, and lower are used only in informal names and are not capitalized.

The major geologic time subdivisions and the estimated ages of their boundaries (after Arthur Holmes and others) are as follows:

Era	Period	Age in millions of years
Cenozoic	Quaternary	
		2-3
	Tertiary*	
		65
Mesozoic	Cretaceous*	
		136
	Jurassic*	
		190-195
	Triassic*	
		225
Paleozoic	Permian*	
		280
	Pennsylvanian	
	Mississippian	
		345
	Devonian	
		395
	Silurian	
		430-440
	Ordovician	
		500
	Cambrian	
		570
Precambrian		

*No deposits recognized in the Chicago area.

The morphostratigraphic classification is used to differentiate units of rocks that have a distinctive form on the present landscape and occur in stratigraphic succession. The moraines deposited by successive stands of glaciers are the principal basis for morphostratigraphic classification in the Chicago area (pl. 1; fig. 15). All the deposits related to the glacier that built a moraine, including the glacial outwash, kames, eskers, lake sediments, and the groundmoraine, even where buried by younger glacial deposits, are included in a unit called a *drift*. Because most moraines result from a temporary stand of the ice front after an interval of advance and before an interval of retreat, the drifts ideally form overlapping, shingle-like sheets, but in many places the older drifts were intensely eroded where overridden by younger glaciers.

The term drift, when used in formal names (Marseilles Drift), is capitalized to differentiate it from the general usage of the term for all the glacial deposits within the glaciated region. In the general usage, drift does not include loess on the glacial deposits or outwash outside the glaciated region.

Another type of morphostratigraphic unit is the alluvial terrace, which includes all remnants of deposits laid down during a particular episode of valley filling. Although terraces occur at several levels along the major rivers in the Chicago area, they have not been formally named, pending more detailed correlations.

The cyclical classification is used to show the repetition of a distinctive sequence of rocks, particularly rocks of Pennsylvanian age (Kosanke et al., 1960). Each unit, called a *cyclothem*, generally consists of basal sandstone overlain in succession by gray shale, limestone, underclay, coal, gray shale, black shale, limestone, and gray shale. Most cyclothems have some of these units missing over wide areas. The sediments in each cyclothem up to the black shale are generally nonmarine or brackish-water deposits, whereas the black shale and overlying sediments in the cycle are marine. The cyclical classification, therefore, is useful in the study of the successive advances and retreats of the Pennsylvanian seas. The distinctive units of the cyclothems are helpful in mapping the economically important coals, underclays, shales, and limestones.

The soil-stratigraphic classification is based on the usefulness of soils as widespread markers, or key beds, in the glacial deposits. The soils indicate significant unconformities, and nine units given the formal name *soil* are named in Illinois (Willman and Frye, 1970). In the Chicago area only the Wisconsinan Farmdale Soil and the soil now forming on the present surface, called the Modern Soil, are present. The older, interglacial soils have been extensively eroded, but they may be encountered in drill holes in some of the deeper bedrock valleys.

The major unconformities in the rock column mark intervals of widespread erosion and, therefore, an interruption in deposition. The strata between the most extensive unconformities are stratigraphic units called *sequences* (Sloss, 1963). Because of differences in the depth of erosion, the age of the beds missing along the unconformities varies greatly, and the boundaries of the sequences cut across both rock- and time-stratigraphic boundaries (Swann and Willman, 1961).

Both the geographic name and the classification name of formal stratigraphic units are capitalized, as in Joliet Formation, Pleistocene Series, Marseilles Drift. The stratigraphic classification to which a unit belongs can always be determined from its name. For example, the Joliet Formation is a rock-stratigraphic unit, the Pleistocene Series is a time-stratigraphic unit, and the Marseilles Drift is a morphostratigraphic unit.

Because the classification of a unit, and therefore its meaning, can be identified from the name, the names are freely intermixed in stratigraphic descriptions and in discussions of geologic history. This introduces an apparent complexity that is resolved by familiarity with the classifications and by recognition of their complete independence. For example, reference to the Wisconsinan Henry Formation means

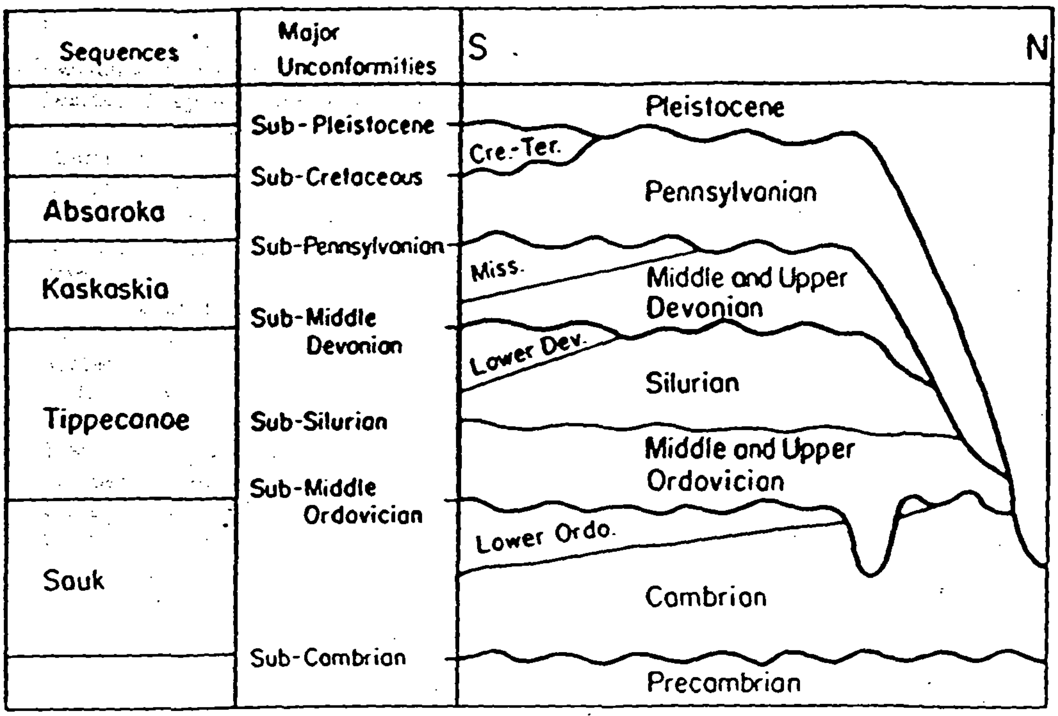

Fig. 6 - Diagrammatic cross section from southern to northern Illinois showing major unconformities and named sequences.

that the Henry Formation is Wisconsinan in age, but the Henry Formation is a rock-stratigraphic unit, not a subdivision of the Wisconsinan Stage. It is differentiated from other formations because of its composition and not because of its age.

STRATIGRAPHIC RELATIONS

Most of the stratigraphic units in the Chicago area have a conformable relation, that is, no significant interruptions in deposition took place. Even though the composition of the sediment changes at the contact between the units, deposition was essentially continuous. At many contacts, however, the lower unit was partly or completely eroded before the overlying sediment was deposited. Contacts where deposition was interrupted and beds are missing are unconformities.

Where the beds above and below an unconformity are essentially parallel, the unconformity is called a disconformity, and where the lower beds were tilted before overlying beds were deposited, the contact is called an angular unconformity. The contact between the Silurian and Ordovician rocks in the Chicago area is a disconformity, whereas the Silurian and Pennsylvanian rocks dip slightly in opposite directions, and the contact between them is an angular unconformity.

Minor unconformities that are of limited extent and represent no great amount of erosion occur between some units, particularly the units differentiated in the glacial deposits. Sharp, undulating contacts between and within many units may be depositional features; they are not unconformities unless there is evidence that beds are missing.

The major unconformities, as previously noted, are used to differentiate units called sequences. A diagrammatic cross section from southern to northern Illinois (fig. 6) shows the stratigraphic relations of the sequences, although it distorts their thicknesses and dips. It reveals the major tectonic events (vertical or tilting movements) and the erosional events in the geologic history of the area. These events are summarized below:

The oldest and deepest rocks in the Chicago area are the Precambrian rocks, which were metamorphosed by heat and pressure at great depths in the crust of the earth. They were intruded by masses of molten rock that cooled slowly, forming granite; later they were uplifted and deeply eroded before late Cambrian time. The sub-Cambrian unconformity represents an interval of time longer than all the time since the beginning of the Cambrian Period. This unconformity is 3,000 to 5,000 feet below the surface in the Chicago area. It is a generally flat surface, but hills of harder rock are locally prominent where the unconformity is exposed in Wisconsin and Missouri (fig. 1).

Only a minor unconformity separates the Cambrian and lower Ordovician (Canadian) rocks that compose the Sauk Sequence. After deposition of the lower Ordovician rocks, the tectonic movements that disturbed major areas in the eastern part of the continent caused uplift, warping, and erosion in the Chicago area. As a result the basal middle Ordovician (Champlainian) St. Peter Sandstone truncates the lower Ordovician rocks and rests directly on Cambrian strata in the central and northern parts of the area (fig. 6). The sub-middle Ordovician unconformity is a rough surface, locally characterized by sinkholes, and it has a prominent escarpment at the margin of the lower Ordovician dolomites (Buschbach, 1961). As lower Ordovician rocks are present again north of the Chicago area, the uplift may represent an early movement along the Kankakee Arch. The unconformity is exposed in the La Salle and Ottawa areas to the west, but it is 300 to 1,000 feet deep in the Chicago area.

The next younger major unconformity is at the base of the Middle Devonian rocks, where it forms the upper boundary for the middle and upper Ordovician, Silurian, and Lower Devonian sediments that compose the Tippecanoe Sequence. Although a widespread but minor unconformity occurs at the base of the upper Ordovician (Cincinnatian) rocks, the surface of the unconformity is nearly flat and only slightly truncates the middle Ordovician rocks.

The end of Ordovician time was marked by uplift, and valleys were cut as much as 150 feet deep in the shale of the upper Ordovician Maquoketa Group. The valleys were filled with early Silurian sediments, but between the valleys there is only slight evidence of unconformity. There is no significant variation in the dip of the rocks, and this unconformity, also, is not comparable to those bounding the Tippecanoe Sequence. In Illinois there is no evidence of an unconformity between Silurian and Lower Devonian rocks in the deep part of the Illinois Basin, and sedimentation apparently was continuous.

The sub-Middle Devonian unconformity at the top of the Tippecanoe Sequence is related to an interval of active tectonic movements in the Appalachian region. As a result of tilting and erosion, the Middle Devonian sediments truncate the Lower Devonian, the upper Silurian (Cayugan), and part of the middle Silurian (Niagaran) rocks north of central Illinois (fig. 6). On local areas of greater uplift, the Middle Devonian strata completely truncate the Silurian and rest on upper Ordovician rocks. In the Chicago area the Middle Devonian strata have been entirely eroded, but the position of the basal unconformity may not have been far above the youngest Silurian in the region. Overlapping Upper Devonian black shale has been found in local pockets on top of the Silurian dolomite and is probably present in the Des Plaines Disturbance. Teeth of Devonian or Mississippian sharks have been found in crevices in the dolomite (fig. 11B). Although Middle Devonian rocks occur both north and south of the Chicago area, Upper Devonian and Mississippian age rocks rest directly on the Silurian in the fault blocks of the Des Plaines Disturbance (fig. 13), and the Chicago area either remained above sea level following the sub-Middle Devonian uplift, or the Middle Devonian rocks were deposited and truncated before or during Upper Devonian time. In either case, the relations appear to result from an uplift of the Kankakee Arch.

The Middle and Upper Devonian and the Mississippian rocks compose the Kaskaskia Sequence, which is bounded at the top by the prominent sub-Pennsylvanian unconformity. A minor unconformity separates the Middle Devonian from the Upper Devonian rocks, but in Illinois there was essentially continuous deposition from Devonian to Mississippian time.

The sub-Pennsylvanian unconformity resulted from regional uplift and upward warping of the Kankakee Arch and other anticlinal structures in Illinois. These movements continued into early Pennsylvanian time and caused deep erosion, during which older rocks were removed from wide areas in the northern part of the state. Subsequent depression of the Illinois Basin (fig. 1) resulted in deposition of Pennsylvanian sediments that northward overlap Mississippian, Devonian, Silurian, and part of the Ordovician rocks (fig. 6). In the southwest corner of the Chicago area, Pennsylvanian strata rest on Ordovician and Silurian rocks (fig. 9), but elsewhere in the area Pennsylvanian rocks generally have been eroded. The local preservation of Mississippian strata in the Des Plaines Disturbance (fig. 13) indicates that these rocks formerly covered the entire area but were eroded from the Kankakee Arch during the development of the sub-Pennsylvanian unconformity.

The Absaroka Sequence consists of the sediments between the sub-Pennsylvanian and sub-Cretaceous unconformites. In Illinois these sediments are all of Pennsylvanian age. Although no major unconformities occur within the Pennsylvanian System in Illinois, the northward overlap results in restriction of earliest Pennsylvanian sediments to southern Illinois. Pennsylvanian sediments formerly covered the entire Chicago area, as is shown by their preservation in the Des Plaines Disturbance. Minor unconformities occur at the base of some of the Pennsylvanian sandstones.

The sub-Cretaceous unconformity represents a long interval of time, from the early part of late Pennsylvanian to late Cretaceous time. At the end of the Paleozoic Era, the Chicago area was uplifted and warped during the major tectonic movements that folded and faulted the formations in the Appalachian Mountains region. The Kankakee Arch was again uplifted and the Pennsylvanian sediments were eroded from most of the Chicago area. There is no evidence that sediment accumulated during this long interval, and consequently no record of the intervals of uplift and depression that may well have taken place. In extreme southern Illinois, Cretaceous and Tertiary sediments rest on warped, faulted, and truncated Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian rocks, and their preservation results from downwarping of the coastal plain. In western Illinois, Cretaceous sediments rest on a relatively flat surface that truncates Mississippian and Pennsylvanian strata. In more distant areas the Cretaceous and Tertiary rocks are divided into two or three sequences (Sloss, 1963).

In Illinois the sub-Pleistocene unconformity truncates all the Tertiary, Cretaceous, and Paleozoic rocks down to the upper Cambrian (fig. 6). This unconformity is the bedrock surface (fig. 9). Although all of this surface has been repeatedly eroded, and in places deeply channeled, during Pleistocene time, it probably is not far (perhaps 100 feet) below the former position of the sub-Cretaceous unconformity. The sub-Pennsylvanian and sub-Middle Devonian unconformities converge on the Kankakee Arch, and these surfaces also may not have been far above the present surface.

FOSSILS

Fossils are common in many of the rock formations in the Chicago area (figs. 7 and 8) and are used to determine the ages of the rocks and the environments in which the rocks were deposited. A great variety of fossil marine invertebrates are common in the Ordovician, Silurian, and Pennsylvanian rocks; plants, insects, and vertebrates are found in the Pennsylvanian rocks; and plants, invertebrates, and vertebrates occur in the Pleistocene rocks (Collinson, 1959).

TABLE 2

PERMEABILITY OF GEOLOGIC MATERIALS*

Type of Material	Approximate Range of Hydraulic Conductivity	Assigned Value
Clay, compact till, shale; unfractured metamorphic and igneous rocks	$<10^{-7}$ cm/sec	0
Silt, loess, silty clays, silty loams, clay loams; less permeable limestone, dolomites, and sandstone; moderately permeable till	$10^{-5} - 10^{-7}$ cm/sec	1
Fine sand and silty sand; sandy loams; loamy sands; moderately permeable limestone, dolomites, and sandstone (no karst); moderately fractured igneous and metamorphic rocks, some coarse till	$10^{-3} - 10^{-5}$ cm/sec	2
Gravel, sand; highly fractured igneous and metamorphic rocks; permeable basalt and lavas; karst limestone and dolomite	$>10^{-3}$ cm/sec	3

*Derived from:

Davis, S. N., Porosity and Permeability of Natural Materials in Flow-Through Porous Media, R.J.M. DeWest ed., Academic Press, New York, 1969

Freeze, R.A. and J.A. Cherry, Groundwater, Prentice-Hall, Inc., New York, 1979